EXHIBIT K

-020

T1X1.4/86- 020

CONTRIBUTION TO T1 STANDARDS PROJECT

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TITLE: "RATES AND FORMATS FOR FIBER OPTIC INTERFACES"

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SOURCE: BELL COMMUNICATIONS RESEARCH, INC.

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NOTICE

1. INTRODUCTION

During the past year and a half, T1X1 has been discussing the development of a standard optical interface. This was motivated by the need to achieve "mid span" meets. Also during this time related conversations have occurred in T1D1 and CCITT concerning broadband ISDN interfaces. The documentation for each of these activities is normally spread over many documents and it is sometimes difficult to keep the important issues clear and in proper perspective.

One may ask why these two seemly unrelated activities are related. If we examine a traditional network of a few years ago (Figure 1), we see virtually all of the processing or switching being done at central offices connected by inter-office trunking. In this arrangement the inter-office facilities needed high capacity links to handle the traffic between the central offices. The loop was a copper pair that originated at the central office and terminated at the subscriber.

Recently electronics has been introduced in the loop to provide a means of gathering many subscriber loops into a high capacity link to the central office. This is illustrated in Figure 2. If one examines the link from the remote electronics and the central office, it looks very much like an inter-office facility in terms of capacity, availability, transmission techniques, and quality requirements. The loop to the subscriber is much shorter but is still twisted pair copper.

Figure 3 illustrates the network that has been conceived by many people to be the network of the future. Both CCITT and T1D1 have undertaken work to define broadband ISDN which requires a high capacity interface (T1D1/85-087) to the customer in order to provide video services. If one examines the link in this network from the remote electronics to the subscriber, it takes many of the characteristics of a present inter-office link, particularly concerning capacity and transport media (most discussions center on a single-mode fiber interface to the subscriber).

It is because the links between central offices, remote electronics, and subscribers are becoming so similar effort should be made to provide a standard interface specification which will satisfy each application's needs. This was recognized in the recent contribution (T1X1.4/86-006). Channelization of the interface is still an open issue, but it is clear that existing standard signals (e.g. DS1, DS1C, DS2, DS3, CEPT-1, and etc) must be efficiently transported to ease the introduction of a standard signal. Additionally, it is clear that services above DS3 rate (particularly video) are desired.

This contribution focuses on the related documents from T1X1 and T1D1 and collects all of the details of a signal rate and format, which has been worked on in T1X1.2/.4 since February, that will satisfy the transport requirements of both activities. The basic concept of this signal is to provide a path for services by defining transport overhead but leaving the information payload flexible which can be channelized at a later date by T1D1 (broadband ISDN), T1C1 (customer interfaces), or T1X1 (loading of DS1,DS3, and etc). Capacity is also allocated to be used for maintenance activities which will be defined by T1M1.

2. RELATED ACTIVITIES AND DOCUMENTS

A joint sub-working group, T1X1.2/.4, was formed to develop rate and format for an optical interface in response to a request from the T1X1.2 sub-working group on optical interfaces. During the initial meeting of the joint group a project proposal (T1X1.4/85-017) was formed to outline and guide the group's activity. Three main points which are present in the proposal are:

1. The group is to concentrate on the establishment of a set of rates and formats for fiber optic interfaces at and/or above 44.736 Mb/s.
2. This activity is to provide a non-proprietary interface which will not constrain proprietary network activities or applications.
3. Consideration will be given to achieve compatibility with the existing digital communications systems to insure an orderly growth toward higher bit rates.

An initial contribution (T1X1.4/85-006) proposed a signal and a multiplexing scheme called a Synchronous Optical Network (SONET). An ad-hoc group was formed to examine the overhead structure and provide a contribution concerning the necessary overhead channels and capacity associated with each. Their report (T1X1.4/85-053R1) is still under revision but contains much useful information concerning the necessary overhead functions. Additional contributions were presented to refine some of the specific functions of each channel (T1X1.4/85-054), justify the need for a modular approach in multiplexing (T1X1.4/86-008), and to suggest a grouping of overhead functions into four categories to help define the need to access each group in a signal (T1X1.4/86-012).

In response to initial comments and contributions, the original rate and format contribution (T1X1.4/85-006) has been revised and reissued as T1X1.4/86-009 and now defines a basic signal rate of 49.920 Mb/s. It is anticipated that this document will be the basis of the standard with further revisions (particularly with the recent BNR contribution describing a pointer scheme for multiplexing).

The existing network and standard signals have driven the rate and format discussions in T1X1. In T1D1 it has been suggested that video services be the most important selection criteria for a wideband channel rate (T1D1/85- 120). If we examine video services, we find that video quality considerations set the lower bound of channel bit rate since video coder/decoder complexity increases as bit rate decreases for a given quality. A range of bit rates can provide various levels of video service quality. For example, NTSC-quality video can be supported with the channel in the range between 40 and 115 Mb/s, extended quality video between 90 and 200 Mb/s, and high definition video between 120 and 400 Mb/s. Video channels should be capable of providing standard and extended qualities; as such, 90 Mb/s is considered a lower bound on the channel. Mechanisms for providing high definition video are for further study.

Switching technology sets the upper bound of the video channel since switching costs increase with switching speed. An assumption is that CMOS technology will be fundamental to the future implementation of broadband switching and transmission systems. A high-speed switching device operating at 150 Mb/s constructed using a commercially available 3 micron CMOS design process has been demonstrated.[1] Emerging design rules at or below the 2 micron level may push the capabilities of CMOS to around 200 Mb/s. Hence, 200 Mb/s is considered as an upper bound on the channel bit rate.

A broadband interface structure that supports a multiplicity of channels has been proposed.[2] Recent high-speed optical transmission experiments have shown that it is possible to drive single-mode fiber with surface- emitting, edge-emitting, and super-radiant LEDs operating at 560 Mb/s over distances of 4.5 km, 15 km, and 25 km, respectively.[3] Hence, a channel bit rate of approximately 150 Mb/s would permit the use of LEDs and single-mode fiber in the subscriber loop to supply up to 4 channels to subscribers. As detailed in later section (3.3), the 150 Mb/s broadband ISDN channel can be defined as a super-rate channel with an integer number relationship between the basic channel rate and the broadband ISDN channel rate. This seems to be a cost-effective implementation for broadband interfaces to ISDN in the near-term and leaves open the future application of laser diodes to subscriber loop transmission systems.

Another consideration in the choice of the channel bit rate is the compatibility with existing or proposed digital hierarchies. The potential for exact compatibility with a proposed network based on bit- interleave multiplexing can only be realized if the channel bit rate is chosen such that existing standard signals can be loaded in the information payload efficiently.

At first appearance, optimization of the transport of existing signals would seem to preclude efficient transport of the suggested broadband video channels. The following sections detail a signal and a multiplexing technique that has been developed by members of T1X1.2/.4 which will satisfy the transport requirements of both.

3. RATES

The basic modular electrical signal shall be termed the "Synchronous Transport Signal level 1", or STS-1. In this proposal, a rate of 49.92 Mb/s is recommended to efficiently carry DS3 and lower rate signals. Broadband services can be provided by an associated "Synchronous Transport Signal level N, or STS-N, where N indicates a rate of N×49.92 Mb/s. Depending on the specific application, N can be any integer between 1 and 256. Table 1 lists some sample services and related synchronous transport signals. STS-N is an electrical signal which can be further multiplexed into a higher rate signal, STS-M, where M > N. An STS-M signal, for an arbitrary M, is transmitted via its optical equivalent, the Optical Carrier level M, or OC-M. Specifications of physical layer characteristics of OC-M is being considered by T1X1.2 fiber optic subworking group. It is recognized that, depending on technology and traffic load, OC-M could be at a rate much higher than that of STS-1 or that of a single super-rate signal. Similarly, when traffic demand is low, an OC-1 could be transmitted as an economic optical carrier signal. The choice of N will be an issue to be negotiated between a manufacturer and his customer. At some future date the range of N might be modified and restricted to facilitate easy interconnectability.

4. MODULARITY

4.1 Uncertain Services, Bandwidth Demands

Many broadband applications are not yet specified or known. Bandwidth demands and bit rates of services change as the technology advances (e.g. encoding algorithms for compression of video signals, advanced digital signal processing implemented in VLSI). Today, broadband services demand a range of bandwidths:

1. High definition TV: 120-400Mb/s
2. Compressed HDTV, broadcast quality video: 90-200Mb/s
3. Conventional video with DPCM coding: 30-115Mb/s
4. High speed data transfer: 6-20Mb/s
5. Video conferencing: 1.5-6Mb/s

Access and transport through the exchange network of these services requires that the fiber interface not only be flexible but also compatible with the future network digital signal hierarchy. A universal network with an ability to evolve is the most important feature of the fiber interface. Economical service can only be achieved in an integrated network design that can handle and transport all these services. A flexible network structure is needed to satisfy the requirements of today and tomorrow.

For broadband services previous contributions have indicated that packet-mode techniques are a way to achieve flexibility at rates lower than the broadband channel rate (T1D1.1/85-113, T1D1.1/85-149). The modular approach described here is necessary to construct channels at rates higher than the STS-1 rate for basic transport of broadband services and to facilitate the introduction of other undefined services.

4.2 Synchronous Multiplexing

The modular approach, which will reduce hardware, maintenance and operating costs, requires that the Nth level signal OC-N, a direct optical translation (no line coding) of the Nth level electrical signal STS-N, is obtained by synchronously multiplexing the modular signal OC-1. Thus, the complexity of the expensive high speed circuits will be limited to simple bit interleaving of STS-1's

allowing complex operations be performed at the lower STS-1 rate in a modular fashion so that high volume VLSI circuits can be employed for cost and power savings. This approach also enables flexible system sizing for expansion by reducing inventories.

4.2.1 Rate and Format of the Basic Module There is an integral multiple relationship between the rate of the basic module OC-1 and multiplexed line signal OC-N.

$$\text{OC-N} = N \times \text{OC-1}$$

Therefore, the definition of the first level signal defines the entire hierarchy. The bit rate chosen for the basic building block, OC-1, is 49.920 Mb/s. Since this rate accommodates current network rates (such as DS3) without format conversion, initial deployment of associated services will be eased. Also, this rate represents a convenient bundle size for network grooming. OC-1 has integral operations, maintenance and administration capabilities and separate overhead and information payload in a flexible TDM frame so that different types of signals can be accommodated. This will ensure reduced network operating costs in a multi-vendor environment.

4.3 Layered Overhead Structure

The modular signal STS-contains an integral overhead structure which allows it to be transported through the network as an independent entity. As an extension of the idea of separating the overhead and payload information for flexibility, a layered overhead structure is proposed. Basically, functions related to STS-N framing, line error monitoring, channel identification and span-to-span communications, maintenance and control channels will be grouped under *span overhead* and payload related functions such as end-to-end error-checking, communications, maintenance and control, payload identification will be grouped under *network overhead (see section 6.1).*

4.4 Super-Rate Services

Super rate services (that require multiples of the OC-1 rate) such as broadband ISDN can be accommodated by transporting the OC-N bundle together. A service that requires such bandwidth can be efficiently transported such that

$$\text{OC-N}' = N \times \text{OC-1}$$

where OC-N' is a bit rate of the channel required by the service. An indication that the OC-N' bundle should be kept together can be contained in the OC-1 overhead. This allows the bundle to be multiplexed, switched and transported through the network as a single entity. For super-rate services, not all of the overhead bandwidth need be utilized for overhead functions. In this manner, there will not be any loss in efficiency in defining the basic module at a lower rate.

5. FORMAT

5.1 STS-1 Frame Structure

Each STS-1 signal is organized into 125 µs frames. Each frame consists of 6240 bits, grouped into 780 bytes. These bytes are further grouped into 30 26-byte blocks. One block is used for overhead functions to be described in the next section, while the remaining bytes are mainly for information payload. For voice applications the information payload could be organized as 754 time slots, each

at 64 Kb/s. For other applications such as data and video services, no format need be defined for the information payload. Instead, it may be considered as a 48.256 Mb/s pipe. To interface the existing digital hierarchical network, STS-1 has the capability of accepting DS1, DS1C, DS2 and DS3 signals. These mappings are currently under consideration. Depending on the specific application, some other organization for the information payload is also possible. The overhead information regarding the actual organization of a particular STS-1 may be transmitted to the far end via overhead channels embedded in the STS-1, to be described in the next section.

5.2 STS-N Frame Structure

An STS-N frame can be envisioned as formed by bit-interleaved multiplexing N STS-1 signals into one high speed bitstream. The actual implementation should be the responsibility of the manufacturers. Often an STS-N signal is formed by bit- interleaved multiplexing N STS-1s, possibly with some intermediate multiplexing stages. In other applications, such as a super-rate service, STS-N can be formed by generating an overhead structure similar to that of N bit-interleave multiplexed STS-1 signals, and mapping the super-rate signal directly into the information payload of STS-N. To provide super-rate services, however, certain phase relationships between the overhead channels of neighboring STS-1s may be imposed. In addition, some overhead channels of individual STS-1s in an STS-N may be redundant and could be ignored or redefined for other purposes.

5.3 STS-1 Overhead Assignments

The frame format for an STS-1 is shown in Figure 4 where the overhead channels are also assigned. The overhead functions considered in this figure are:

Framing channels - A1, A2
Error monitoring - B1, B2
Channel identification - C1, C2
User facility maintenance and control - D1, D2
Order-wire - E1, E2
User proprietary channels - F1, F2, F3
Manufacturer's proprietary channels - G1, G2
Frame Alignment control - H1, H2, H3
Growth channels - J1 to J7

and they are listed, with their assigned locations, in Table 2.

6. OVERHEAD FUNCTIONS

6.1 Classifications

The above-mentioned overhead functions will be defined and classified into various categ ies. One possible breakdown is:

1. Those functions required on every facility.
2. Those functions that are intimately related in a real-time sense to the bit patterns being transported.
3. Those functions that require communication between the terminal control computers.
4. Those functions that are application dependent.

Another breakdown is:

1. Sectional
2. Multiplexer span
3. Optical network
4. Service path

6.2 Definitions

Framing - Two framing channels (A1, A2) are recommended for each STS-1. The reframe is accomplished by examining the 8-bit blocks until one of the two subframing patterns is identified. Then the other pattern is tracked. This reframing technique requires minimal circuitry and has a reframe time of about 1 msec.

Channel error monitoring - This function consists of two 8-bit channels (B1, B2). A cyclic redundancy check code-8 (CRC-8) for section and span error-check and a CRC-8 for network error-check.

Span channel identification (C1) - This is a unique number assigned just prior to multiplexing that stays with that STS-1 until demultiplexing. In a multiple stage multiplexer C1 is modified at each stage.

Network signal label channel (C2) - This channel defines how the information payload is organized in the frame and how it is constructed. It will be used to identify asynchronous DS3, SYNTRAN, digital video, etc. payloads and to include the need to group multiple payloads, if such payload exists.

Span maintenance and control (D1, D2) - These are for automatic switching, fault locating, terminal and switching office surveillance and other span-to-span measurements. Specific channel definition and usage of these two channels will be determined by T1M1.

Network maintenance and control (D3) - This channel is assigned for the monitoring, control and analysis of the multi-span networks. It is made available for packet switching and centralized maintenance applications.

Order-wire - Two order wire channels are allocated: local (E1) and express (E2). These are reserved for communication between central offices and, where required, regenerators, hubs and remote terminal locations. This reservation is in line with current industry practices.

Span user proprietary channel (F1) - This is allocated to the EC/IEC user for his input of span information such as data communication for use in maintenance activities and remoting of alarms external to the span equipment.

Network user proprietary channels (F2, F3) - These are for EC/IEC use as end-to-end VF communication channels for themselves and/or their end users.

Manufacturers proprietary channels (G1, G2) - Two span oriented channels are recommended to be reserved for manufacturer's use for unique enhancements he might introduce.

Frame alignment control - Three channels are recommended to allow for asynchronous impairments in an otherwise synchronous network. The first two (H1, H2) are redundant channels that are used for indicating the action to be performed, i.e., clocks in instantaneous synchronization. The third channel (H3) is the bit to be acted upon. (Note: This channel will contain 7, 8 or 9 bits - depending on H1/H2. Seven bits of this channel are available for other assignments.) A newly recommended pointer scheme uses the same frame alignment channels to allow an alignment of all framing patterns of the tributaries. The information payload of the tributaries need not be phase-aligned. Instead, their locations are indicated by the framing alignment channels. Asynchronous impairment of the tributary is automatically accommodated by H3 as well.

Growth channels - Seven channels (J1 through J7) are allocated to future growth needs for the industry. Additional growth channels may become available as some of the above requirements are

refined. The final format was designed with this latter factor in mind.

7. MULTIPLEX PROCEDURE

7.1 Bit Interleaved Multiplexing

Nth level optical carrier OC-N will be a direct optical translation of the Nth level electrical signal STS-N. STS-N signal will be formed by bit-interleaving the tributary STS-1 bit streams without additional overhead. Therefore, the line rate will be $N \times 49.920$ Mb/s. To eliminate high speed processing, no line decoding will be used. Framing can be achieved by bit de-interleaving the STS-N signal and monitoring framing bytes in any of the serial bit streams from the de-interleaver. Once in frame, the number for that channel is obtained by observing the span channel ID byte in the span overhead and ordering of the channels can be corrected. This method allows an STS-1 rate framer.

7.2 Frames and Pointers

The transmission frame of the STS-1 structure (30×26 bytes) and the source structure (29×26 byte payload) will be decoupled to facilitate super rate services, to avoid difficulties in framing due to a defective source frame and to eliminate frame buffers at cross-connects. According to this scheme, the *source frame* can float inside the payload structure. However, to avoid two stages of framing, the information concerning the location of source frame is conveyed by a pointer in the transmission frame. A 10-bit pointer word which carries the byte number of the start of the source frame is required. Two bytes in the span overhead can be allocated for that purpose (H1, H2).

All span-related functions, framing, span ID, pointer, error monitoring and span operating and control are carried in the span overhead which is interlocked for all STS-1s. This allows super-rate services to perform the necessary operations for multiplexing/demultiplexing without breaking down to component STS-1s. All other functions related to the network are linked to the source frame and depend on the type of payload.

The pointer concept can be extended to the source frame for single step framing down to components of the payload.

7.3 Scrambling

Scrambling is required to achieve sufficient density of state transitions on the line for timing recovery. A self-synchronous scrambler with a monitoring logic which prevents long strings of ones or zeros can be used. Scrambling operation can be performed either before or after bit-interleaving. In either case, the operation has to be performed at any interface where access to overhead or payload information is required, since all the bits, including framing, will be subject to scrambling. In this way, scrambling will be independent from and transparent to the frame and format of the STS-1 signal.

The length and type of the shift register generator should be determined after more study.

8. Conclusion

The detail of a rate and format with a multiplexing technique which has been developed in T1X1.2/.4 has been presented. While further refinement must be made and details of several sections must be filled out, this document will serve as the basis for the standard. It has been shown

that by taking into consideration many views and contributions from a variety of organizations, principally T1X1 and T1D1, a standard optical interface can be defined which will satisfy the transport needs of the present network, the broadband ISDN network, and still provide flexibility for transport of future as yet undefined services by placing very few constraints on the information payload structure.

9. RECOMMENDATION

This document has gathered together in one place the related contributions and discussions concerning the optical interface specifications. It is recommended that this information be taken and turned into a draft standard document to be reviewed in the May meeting.

REFERENCES

1. J. Berthold, et al., "A High-Speed 16 x 16 CMOS Crosspoint Switch," Electronics Letters, Vol.21, No.20, September 26, 1985, pp. 923-932.

2. T1D1/85-122, "Interface Structures for ISDNs Providing Broadband Services."

3. J. L. Gimlet, et al., "Transmission Experiments at 560 Mb/s and 140 Mb/s Using Fiber and 1300 nm LEDs." Proceedings of the 11th European Conference on Optical Communication, Venice, Italy, October 1985.

SIGNALS ACCOMMODATED BY 49.920 MB/S

DS1 DS1C DS2	DS3	DS4E	EQ VIDEO	HD VIDEO
STS-1	STS-1	STS-3	STS-3	STS-12

TABLE I

FRAMING SUBFRAME 1 A1	NETWORK MAINTENANCE CHANNEL D3	FRAME ALIGNMENT INDICATOR H1	FRAME ALIGNMENT INDICATOR H2	FRAME-OF-ACTION BIT H3	GROWTH CHANNEL 1 J1	SPAN MAINTENANCE CHANNEL 1 D1	SPAN MAINTENANCE CHANNEL 2 D2	SPAN ERROR-CHEC B1
1	2	3	4	5	6	7	8	9
NETWORK ERROR-CHECK B2	SPAN ID C1	USER SPAN PROPRIETARY CHANNEL F1	GROWTH CHANNEL 2 J2	FRAMING SUBFRAME 2 A2	USER NETWORK PROPRIETARY CHANNEL 1 F2	USER NETWORK PROPRIETARY CHANNEL 2 F3	GROWTH CHANNEL 3 J3	NETWORK SIGNAL LABEL C2
10	11	12	13	14	15	16	17	18
LOCAL ORDER WIRE E1	EXPRESS ORDER WIRE E2	GROWTH CHANNEL 4 J4	GROWTH CHANNEL 5 J5	GROWTH CHANNEL 6 J6	GROWTH CHANNEL 7 J7	MANUFACTURER PROPRIETARY CHANNEL 1 G1	MANUFACTURER PROPRIETARY CHANNEL 2 G2	
19	20	21	22	23	24	25	26	

Table 2

FSI058573

TRADITIONAL NETWORK

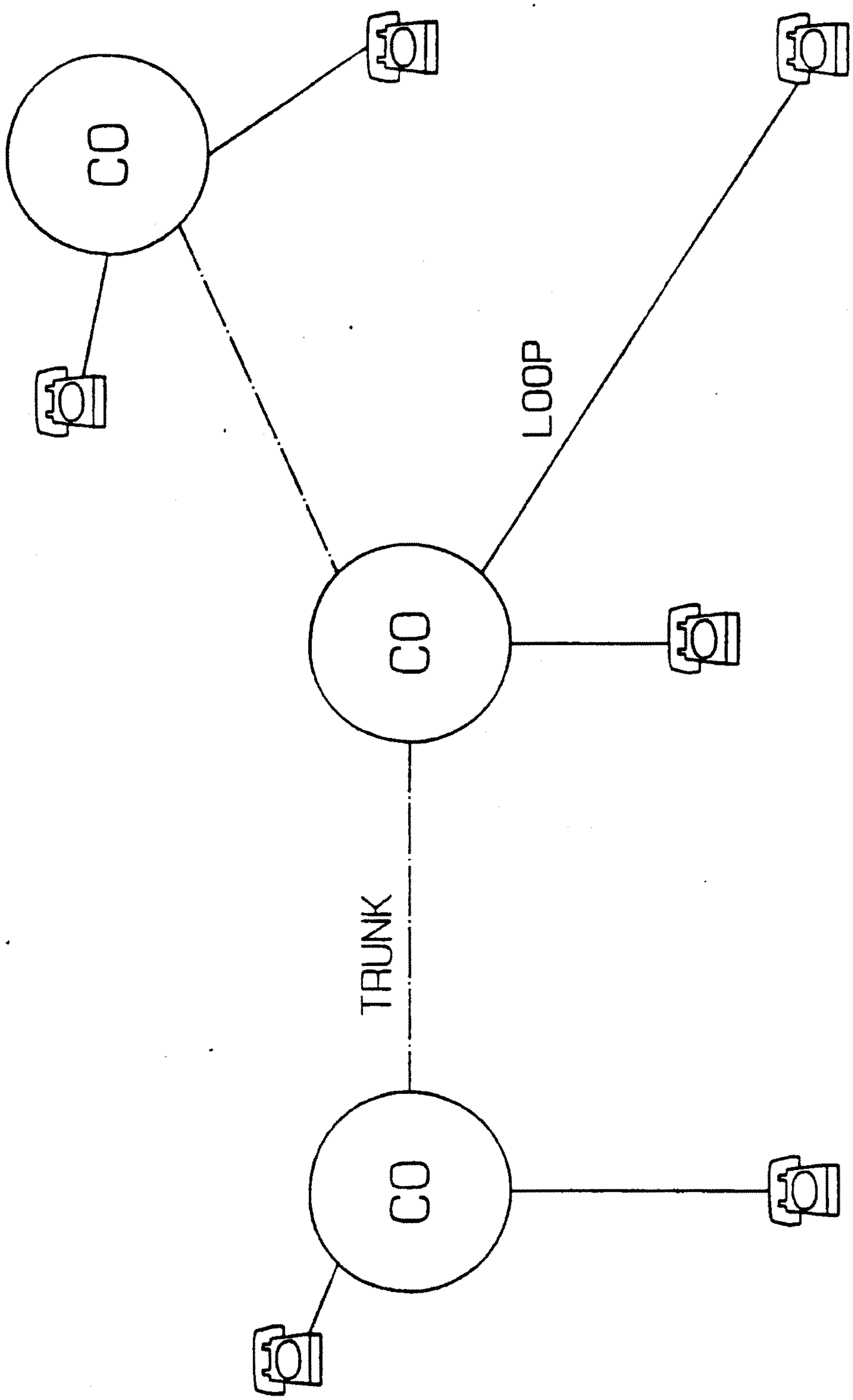

Figure 1

PRESENT NETWORK

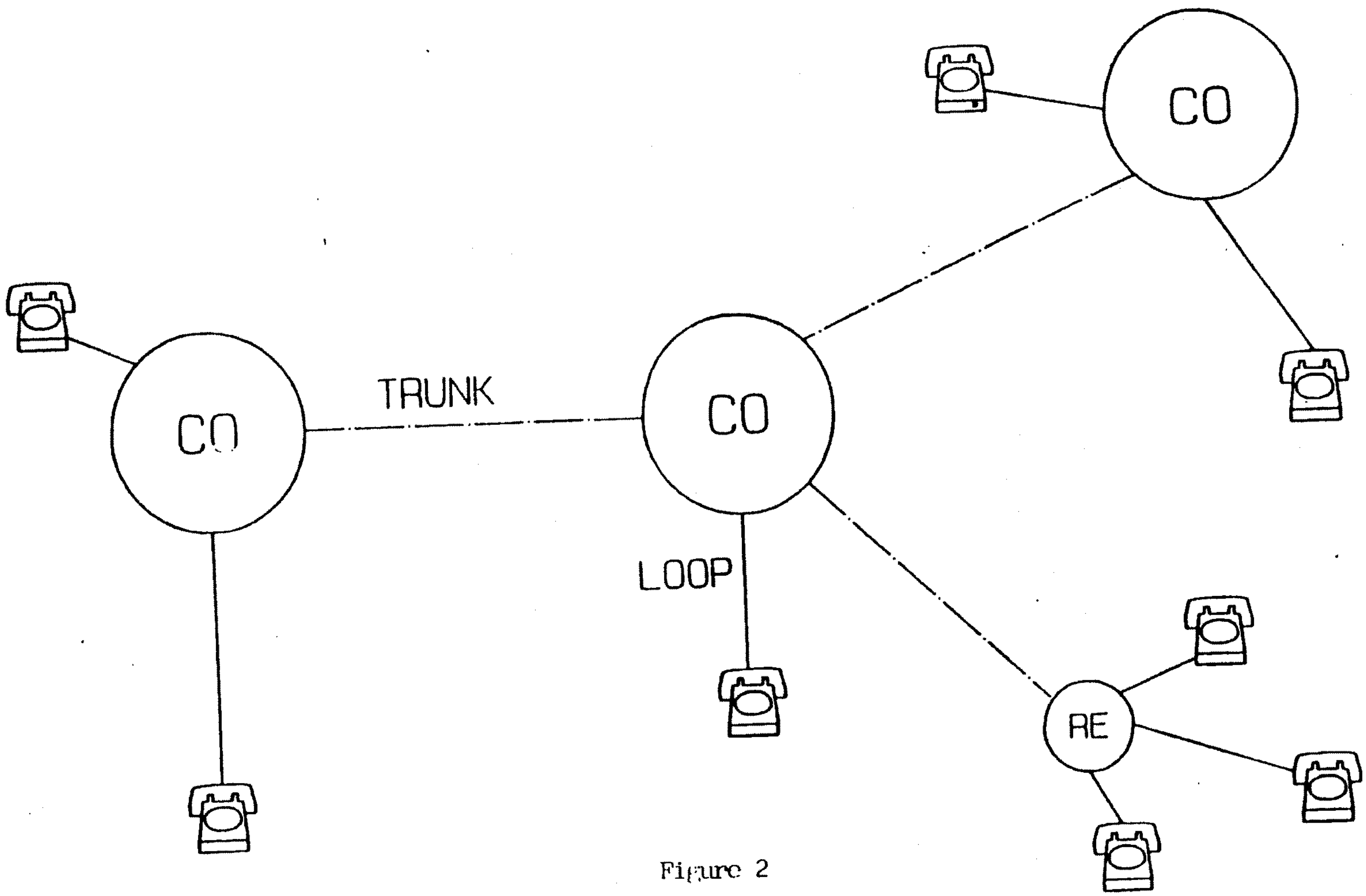

Figure 2

FUTURE NETWORK

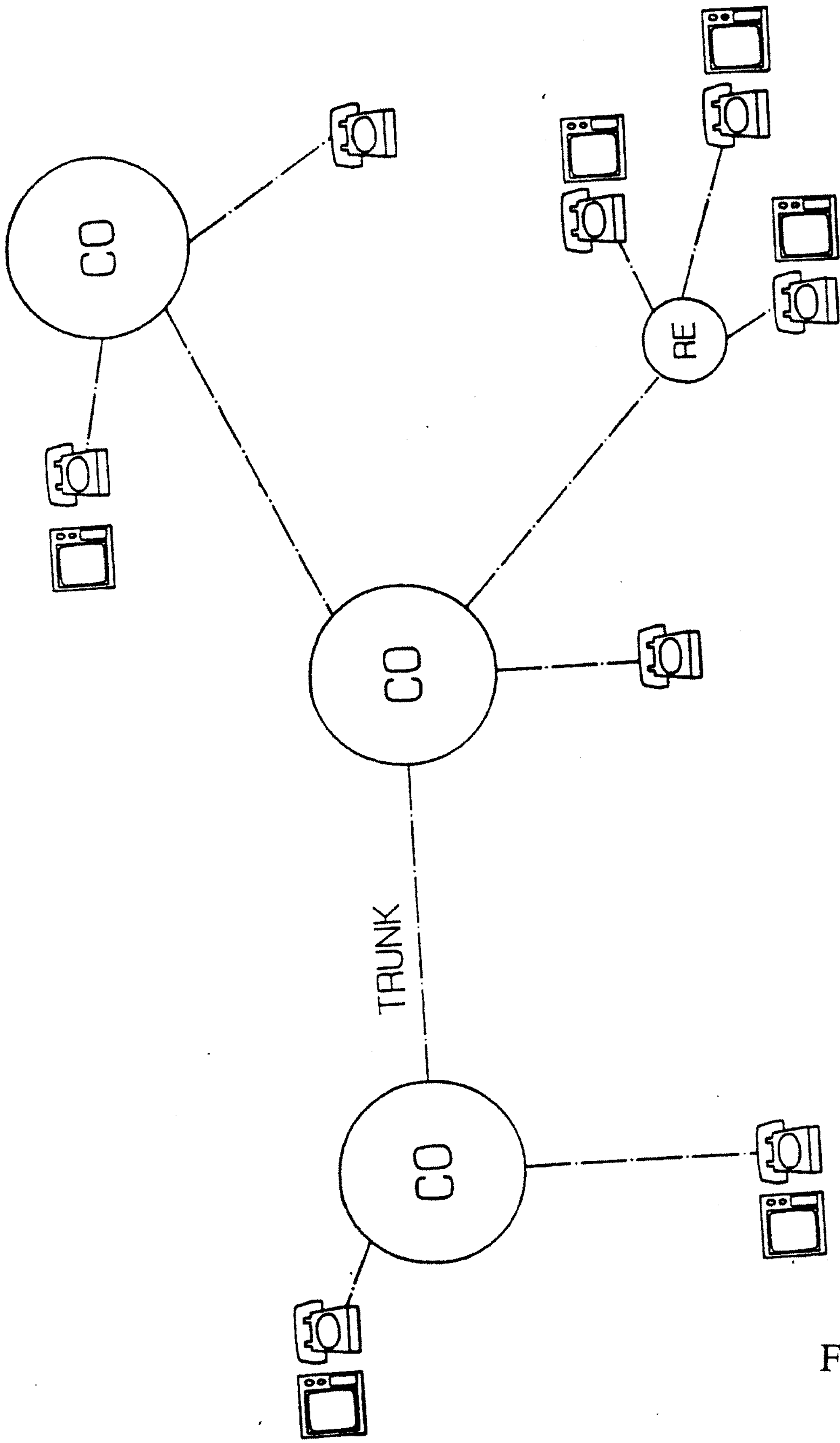

Figure 3

FRAME FORMAT

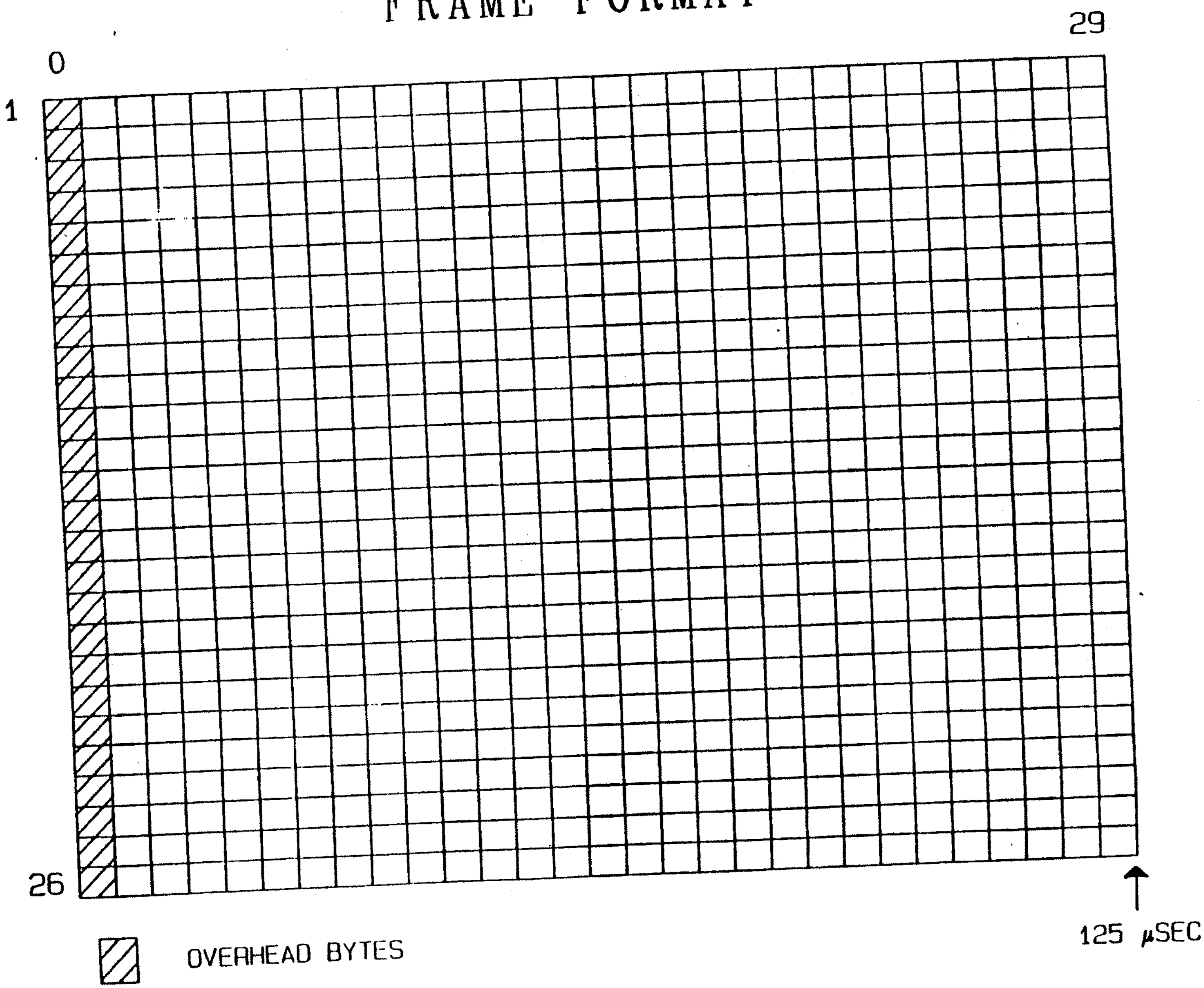

Figure 4